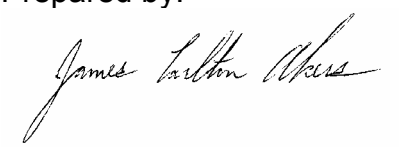
Multi-User Droplet Combustion Apparatus (MDCA)

Acoustic Emissions Test Plan

Planned Test Date: June 4 & 7, 2004

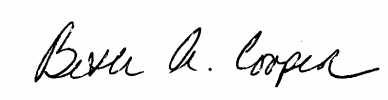
Prepared by:



5/24/04

Analex/James Akers, Ph.D. Date
ATL Test Engineer

Approved by:



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TEST PLAN

Multi-User Droplet Combustion Apparatus (MDCA)

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Prepared for

Northrop Grumman Information Technology

Planned Test Date: June 4 & 7, 2004

ACOUSTICAL TESTING LABORATORY

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1. Introduction.

This document will serve as the requirements document and the test plan for acoustic emissions testing of a flight hardware Multi-User Droplet Combustion Apparatus (MDCA). The MDCA is comprised of two pieces. The first piece is a Chamber Insert Assembly (CIA) that resides inside the combustion chamber of Fluids and Combustion Facility (FCF) Combustion Integrated Rack (CIR). The second piece is an Avionics Package (AP) that mounts to the front of the CIR Experiment Assembly (i.e. the CIR optics bench). These test articles will be referred to as the MDCA CIA and MDCA AP, respectively, in this document.

1.1. Test Objective

The objective of this test is to measure acoustic emission levels of MDCA for purposed of comparison with the limits specified in FCF-ICD-CIR-MDCA Rev B for both continuous and intermittent acoustical noise. FCF-ICD-CIR-MDCA Rev B specifies the acoustical noise limits for payloads that will reside in CIR. The continuous noise limits are listed in Table 1. Likewise the overall A-weighted sound level limits and the associated allowable maximum time duration limits are listed in Table 2.

One-third octave band acoustic emissions data will be acquired and post processed into equivalent octave band data. Sound pressure level data only will be acquired. Sound power levels will not be determined during this series of tests.

Table 1. Continuous Acoustic Noise Limits.

Octave Band Center Frequency (Hz)	Total Rack Based on NC-40 (dB)	Payload Within Combustion Chamber (dB)	Payload Outside Combustion Chamber (dB)*
63	64	57	54
125	56	51	48
250	50	60	49
500	45	60	50
1000	41	60	49
2000	39	58	46
4000	38	57	46
8000	37	56	46

Note: (*) Includes the CIR configurable hardware.

Table 2. Intermittent Acoustic Noise Limits.

Time NC-40 is Exceeded During a 24-Hour Period (1)	Total Rack A-Weighted Sound Level (2) (dBA)	Payload Within Combustion Chamber A-Weighted Sound Level (dBA)	Payload Outside Combustion Chamber A-Weighted Sound Level (3) (dBA)
8 Hours	49	46	36
7 Hours	50	47	37
6 Hours	51	48	38
5 Hours	52	49	39
4.5 Hours	53	50	40
4 Hours	54	52	42
3.5 Hours	55	53	43
3 Hours	57	55	45
2.5 Hours	58	61	51
2 Hours	60	62	52
1.5 Hours	62	65	55
1 Hour	65	68	58
30 Minutes	69	72	62
15 Minutes	72	76	66
5 Minutes	76	80	70
2 Minutes	78	82	72
1 Minute	79	83	73
Not Allowed	80	84	74

Notes:

(1) If the noise from the payload were at the level in this table for the duration specified in this column, no other payload operation would be permitted during the remainder of the 24-hour period.

(2) A-weighted Sound Pressure Levels (SPL), dB referenced to 20 micropascals. Measured at 0.6 meters (1.97 foot) distance from the noisiest surface with equipment operating in the mode or condition that produces the maximum acoustic noise. Round dBA to the nearest whole number.

(3) Includes the payload components and CIR configurable components.

1.2. Scope

This test plan defines the acoustic emissions test specifications relating to acoustic measurements to be performed on the MDCA. These specifications include the test setup, instrumentation requirements, operational configurations, and data products. This test plan does not detail the step-by-step procedures by which the test will be executed.

1.3. Applicable Documents

Multi-User Droplet Combustion Apparatus Interface Control Document, FCF-ICD-CIR-MDCA Rev B: December 2003.

4.10.1.2.1 Continuous Noise Limits
4.10.1.2.2 Intermittent Noise Limits

2. Customer Contacts

The customer contacts for the MDCA acoustic emissions tests are listed in Table 3. In addition software engineers, mechanical engineers, electrical engineers will be present as needed. Quality assurance personnel will also be present during testing. A representative of the Customer will be present at all times when the MDCA is being tested or handled.

3. Test Schedule.

The MDCA AP is scheduled to be installed in the NASA Glenn Research Center Acoustical Testing Laboratory (ATL) test chamber Friday afternoon, June 4, 2004. Set up of support equipment and instrumentation will also occur at this time. The acoustic emissions testing will begin Monday morning, June 7, and continue through Wednesday, June 9, as required to complete all testing.

Table 3. MDCA customer contact list.

Person	Title	Phone Number
Craig Myhre	GRC MDCA Project Manager	(216) 433-8741
Brian Borowski	MRDOC MDCA Project Manageer	(216) 925-1192
Joel Knapp	MDCA Systems Lead	(216) 925-1060

4. MDCA Test.

4.1. Test Article Description

The MDCA test article is comprised or two test articles, a flight hardware MDCA CIA and a flight hardware MDCA AP. The MDCA CIA is cylindrical with a diameter of approximately 9.9 cm (14 inches) and an overall length of 66 cm (26 inches). The MDCA CIA will be supported with a cradle fixture having rollers that allow the MDCA CIA to be rotated about its longitudinal axis. The MDCA CIA and cradle fixture weigh less than 45 kg (100lb). The MDCA CIA in the cradle fixture during buildup in the high bay of Building 333 is shown in Figure 1 and Figure 2. The Dispensing System, Droplet Deployment System, Retractable Indexing Fiber mechanism, and the Ignition System in the engineering model (EM) of the MDCA CIA are shown in Figure 3 through Figure 6. The MDCA CIA will not be fueled during this test and therefore no combustion will take place during this test.

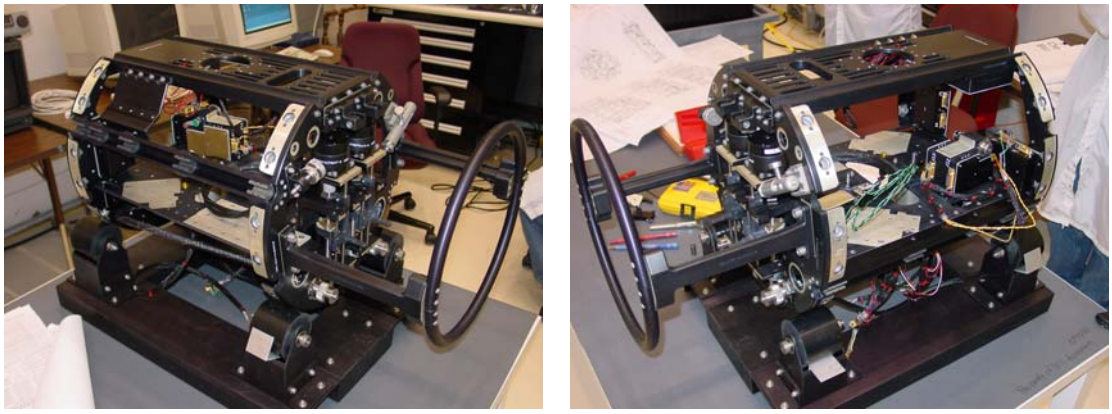

Figure 1. Left side (l) and right side (r) of the MDCA CIA during buildup in Building 333 high bay.

The MDCA AP provides the processing and control interface hardware for controlling the MDCA CIA and communicating with the CIR hardware. The MDCA AP controls the MDCA CIA motors, provides the functions for input and output data control, and is the source for experimental data collection. The MDCA AP receives 28 VDC from the CIR. The MDCA AP is a rectangular box with overall dimensions of 28 cm (11 inches) wide x 33 cm (13 inches) tall x 25 cm (10 inches) deep.

For purposing of testing, the MDCA AP will be mounted to an Optics Bench Simulator (OBS) that provides cooling, electrical power, and data interface. The OBS is a rectangular box with overall dimensions of 41 cm (16 inches) wide x 33 cm (13 inches) tall x 46 cm (18 inches) deep.

The OBS has a single cooling fan on one side. The MDCA AP mounted to the OBS during buildup in Building 333 high bay is shown in Figure 7 and Figure 8. The MDCA AP and OBS weigh less than 45 kg (100 lb). The OBS has a 28VDC power cable (power to the MDCA CIA), a 24 VDC power cable (power to the OBS cooling fan), and an Ethernet cable (data interface with the MDCA AP) running into it. A single cable bundle, that carries both power and data, connects the MDCA AP to the CIA.

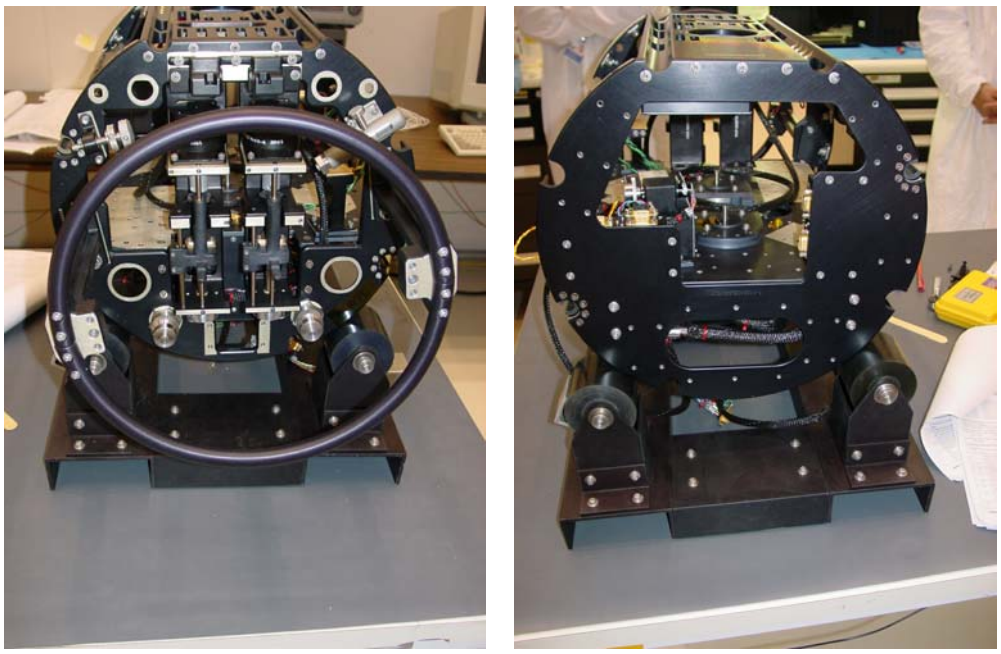

Figure 2. Front side (l) and back side (r) of the MDCA CIA during buildup in Building 333 high bay.

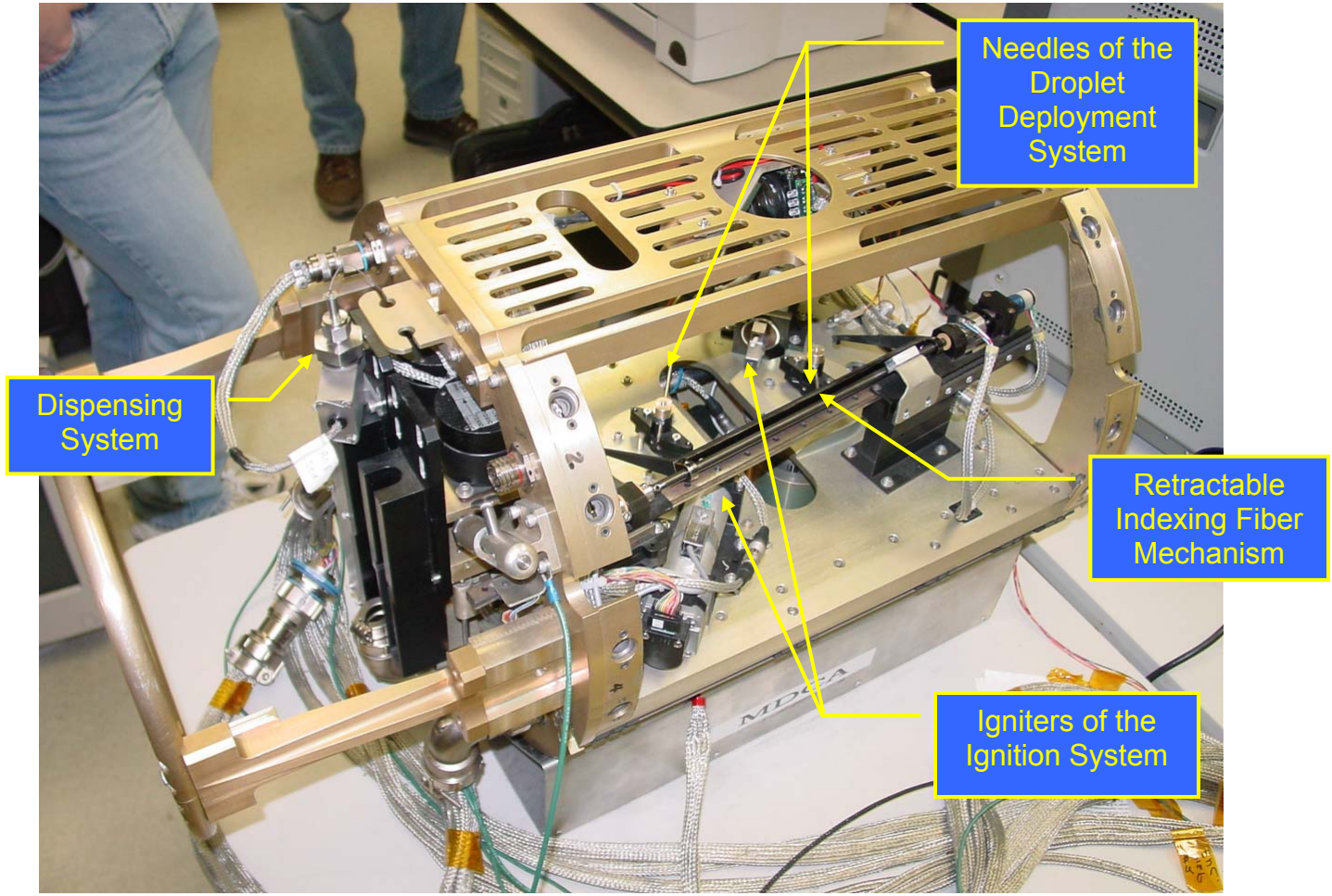

Figure 3. MDCA CIA Engineering Model (EM).

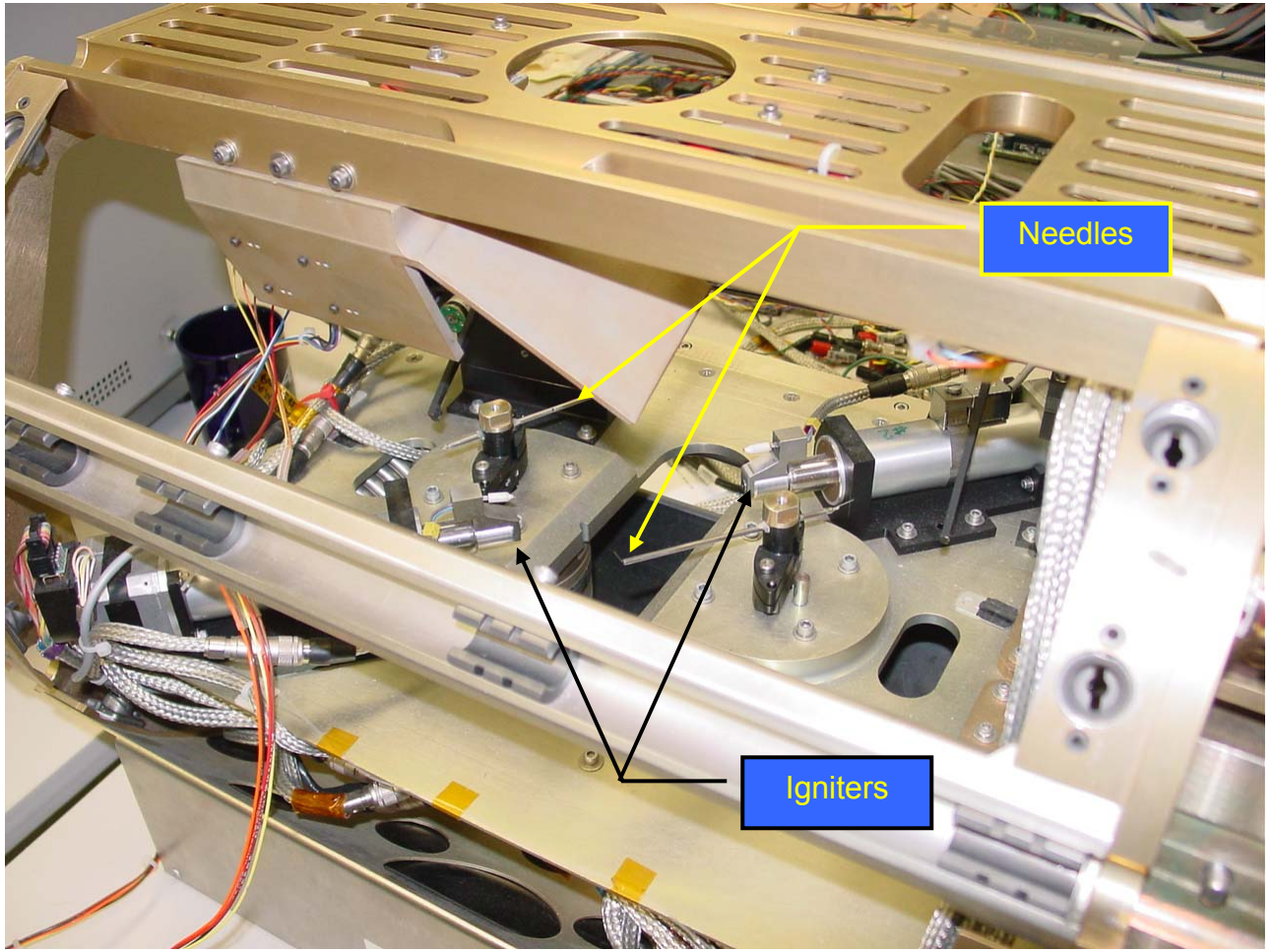

Figure 4. Close up of the needles of the Droplet Deployment System and the igniters of the Ignition System in the MDCA CIA EM.

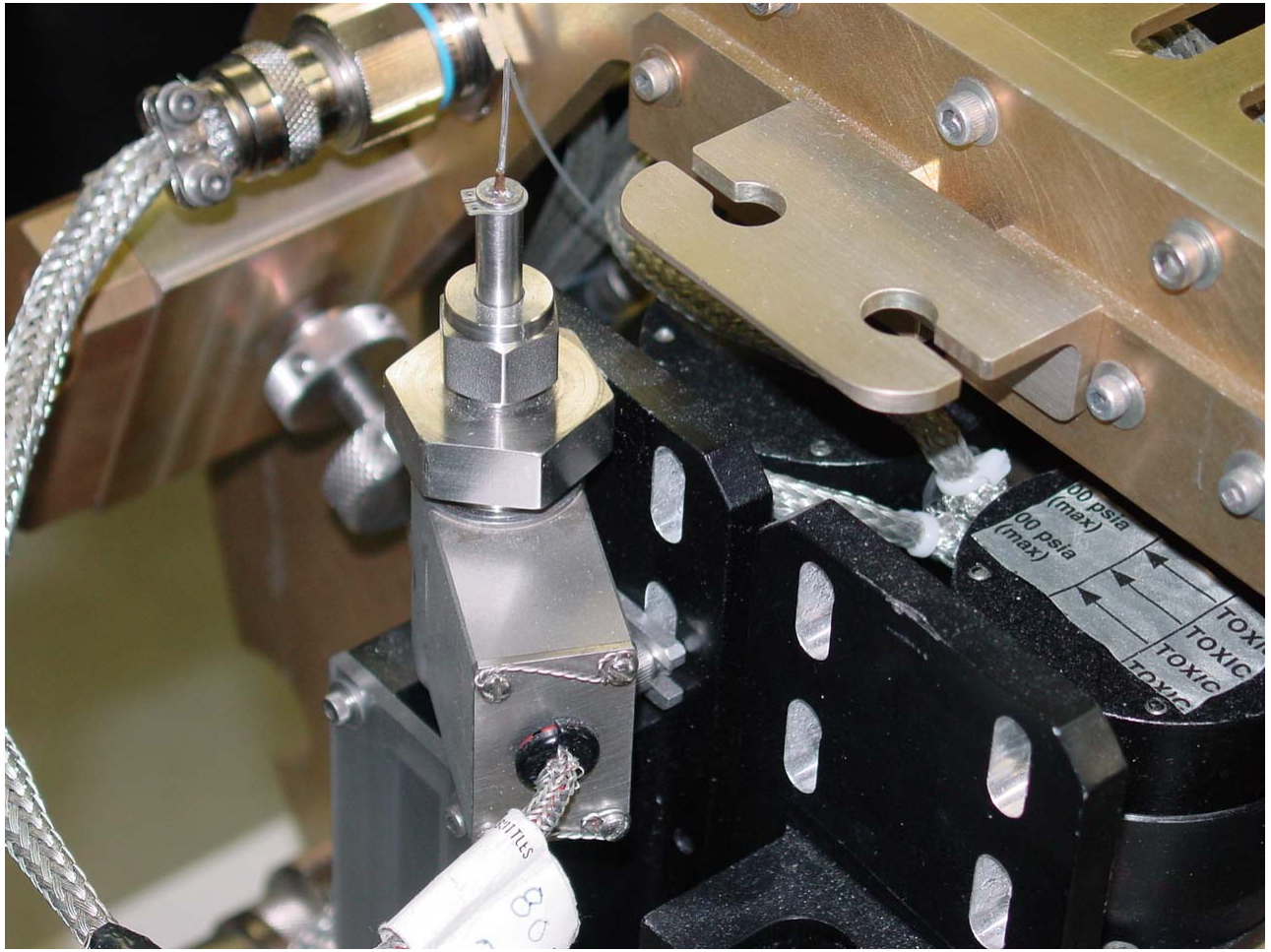

Figure 5. Close up view of the Dispensing System in the MDCA CIA EM.

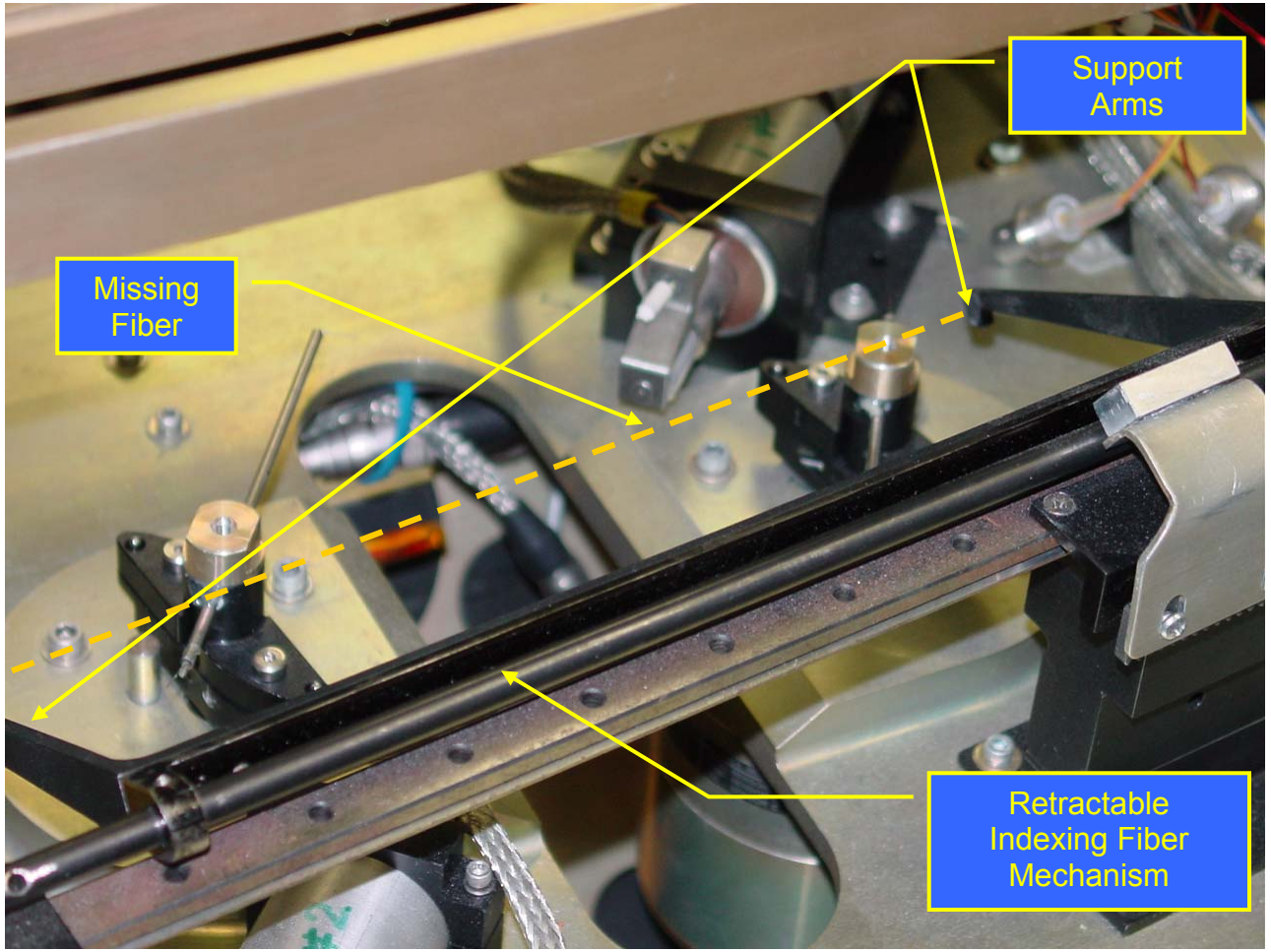

Figure 6. Close up view of the Retractable Indexing Fiber mechanism in the MDCA CIA EM. (Note that the fiber that runs between the two support arms is not present in this photo.)

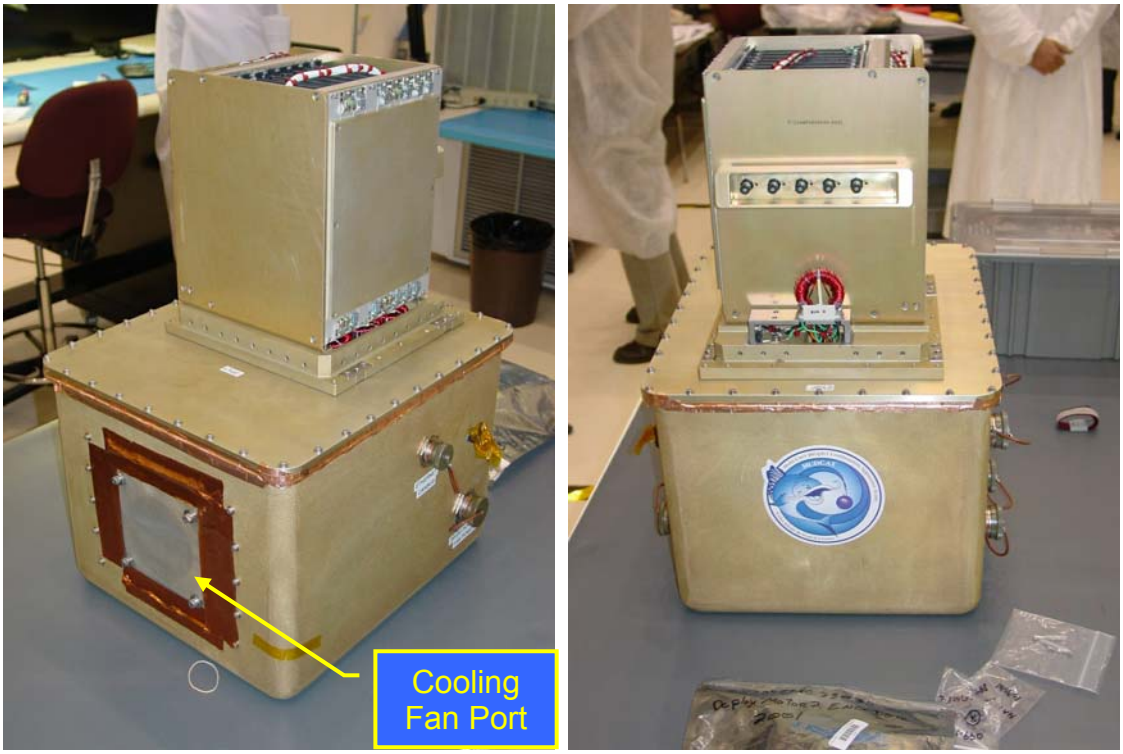

Figure 7. Two views of the MDCA CIA mounted to an OBS during buildup in Building 333 high bay.

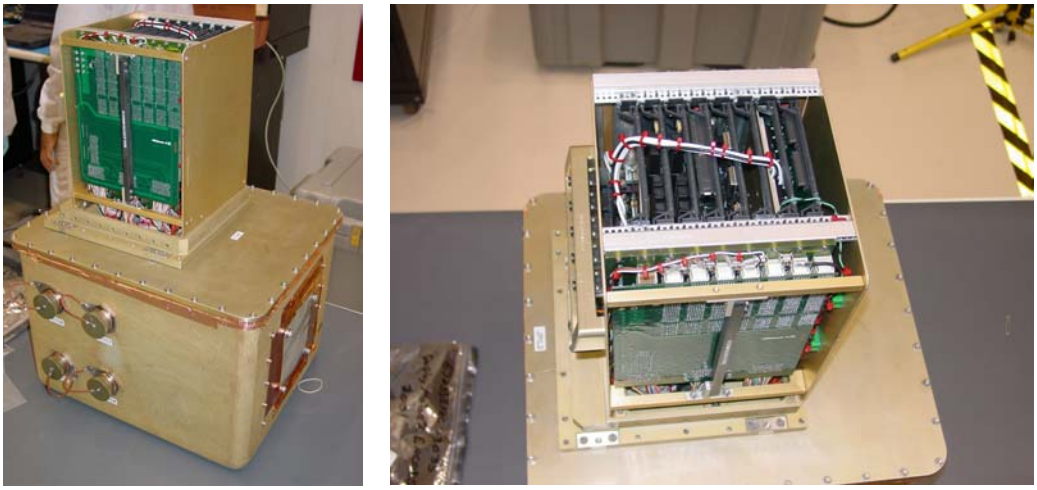

Figure 8. Two more views of the MDCA CIA mounted to an OBS during buildup in Building 333 high bay.

4.2. Test Facilities and Equipment

The acoustic emissions testing of the MDCA will be conducted in the NASA Glenn Research Center (GRC) Acoustical Testing Laboratory (ATL), located inside of the Bldg. 333 Annex. The ATL test chamber will be configured in its anechoic mode with the grating floor installed. The ATL test chamber and control room HVACs will be off during all testing. The Building 333 Annex HVAC will be on during all testing.

The humidity level inside the ATL test chamber will be monitored at a location close to the center of the room. The relative humidity inside the ATL test chamber will be maintained between 30% and 50% for the duration of the test with a humidifier (dehumidifier) as required. The humidifier (dehumidifier) will be located in the Northwest corner of the ATL test chamber as shown in Figure 9. The humidifier (dehumidifier) will be left in place, turned off, and covered with acoustically absorptive panels during data acquisition as shown in Figure 9.

Figure 9. Humidifier located in the Northwest corner of the ATL test chamber uncovered (left) and covered (right).

4.3. Test Support Requirements

The Customer will supply a support computer to operate the MDCA and power supplies to provide the 24VDC and 28 VDC to the OBS. The Customer will also supply the data interface and power cables that connect the power supplies and support computer to the OBS and the MDCA AP to the CIA. The cable connecting the MDCA AP to the CIA will be approximately 12 foot long. The cables running from the power supplies and the support computer to the OBS will be a minimum of 25 foot long. The support computer and the power supplies will be located in the ATL control room and will run off one or more of the 120 VAC outlets located throughout the control room.

The OBS will be grounded with an independent ATL grounding cable. ATL will provide grounding wrist straps, ESD smocks, hair covers, and static dissipative gloves for all personnel, as needed, to protect the MDCA test article from electrostatic discharge and contamination.

ATL will provide a dedicated phone for the Customer (phone number (216) 433-2065), which will have voice mail.

4.4. Test Setup

All support equipment will be located in the adjoining ATL control room. The power and data cables will pass through utility penetration ports that pass through the West wall of the control room and into the East wall of the test chamber. The Customer is responsible for installing and removing all of their support equipment from the ATL control room. The Customer may store their support computers and other equipment in the ATL control room overnight.

All data acquisition equipment and personnel will also be located in the ATL control room during all testing.

Per the Customer, the MDCA is considered flight hardware. The Customer will be responsible for installing and removing the test articles from the test chamber. The OBS will be grounded with an independent grounding cable, supplied by ATL, at all times in the test chamber.

Figure 10. Wedges removed from the modified 3 foot by 3 foot wedge cart will be used to fill back in where the wedge cart would normally be placed.

One of the 3 foot by 3 foot wedge carts that normally fills in next to the large double doors of the ATL test chamber will be removed and used as a test fixture to support the FCF IOP Package. The wedges from this wedge cart will be removed and used to fill in the spot left empty by the removal of the wedge cart as shown in Figure 10. This wedge cart will placed up on the main grating floor at the center of the test chamber. Four 2-foot extension posts will be used to elevate this wedge cart's grating floor section so that it will be 1.57 meters (62 inches) above the main grating floor. Acoustically absorptive foam, shown in Figure 11, will be used on the bottom of the wedge cart to reduce any acoustical reflections off the cart's structural members.

Figure 11. Bottom of the modified 3 foot by 3 foot wedge cart after the wedges have been removed will have foam padding installed.

The MDCA will arrive at the ATL in two shipping cases that each are small enough and light enough that they each can be hand carried by two individuals. The MDCA CIA and its cradle fixture are small enough and light enough that they will be hand carried by the Customer into the test chamber. Also the MDCA AP mounted to the OBS is small enough and light enough that it will also be hand carried by the Customer into the test chamber. The Customer will be responsible for installing the MDCA CIA and its cradle fixture, and the MDCA AP attached to the OBS on top of the modified wedge cart's elevated section of grating floor in the test chamber. ATL personnel will provide support as needed by the Customer.

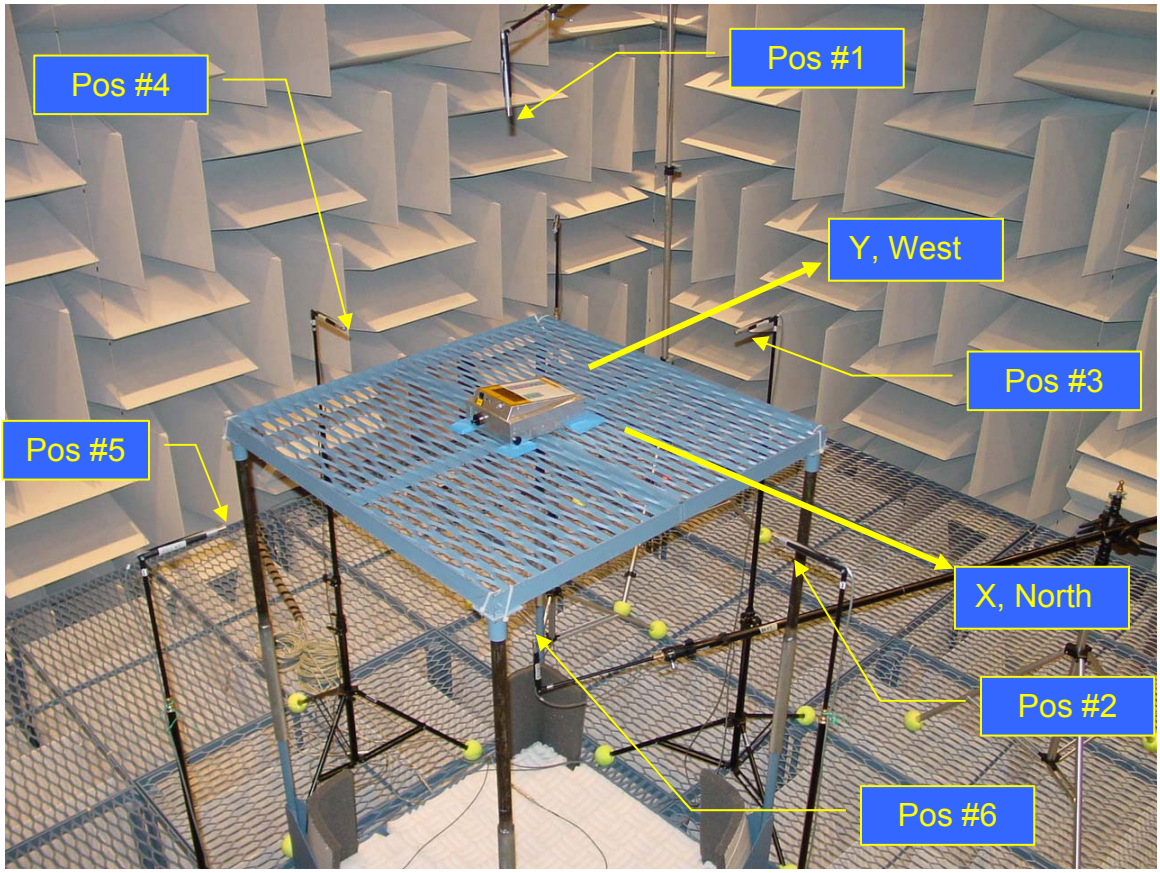

Figure 12. Modified 3 foot by 3 foot wedge cart used as a test fixture and microphone layout from a previous test.

First the MDCA AP mounted to the OBS will be placed by hand on top of the modified wedge cart's elevated section of grating floor. Small foam pads will be placed under the OBS to prevent it from rattling on the elevated section of grating floor. The MDCA AP will be turned on, the OBS cooling fan turned off, and sound pressure level data will be recorded.

Next the MDCA AP mounted to the OBS will be removed from the top of the elevated section of grating floor of the modified wedge cart and replaced with the MDCA CIA in its cradle fixture. The MDCA AP mounted to the OBS will be placed down on the main grating floor as far away from the modified wedge cart as its cables allow. Small foam pads will be placed under the OBS to prevent it from rattling on the main grating floor.

The MDCA CIA in its cradle fixture will be place on top of the modified wedge cart's elevated section of grating floor similar to that shown in Figure 12. The front of the MDCA CIA will face North (X+ direction). It will be positioned inside the ATL test chamber as close to the center of the room as possible. Small foam pads will be placed underneath the corners and edges of the MDCA CIA cradle fixture and the OBS to prevent them from rattling on the elevated section of grating floor. Care will be taken to minimize the size of the foam pads to prevent blocking or reflecting acoustic emissions.

The MDCA CIA will be put into a continuous loop of its operating cycle, the OBS cooling fan will turned off, the MDCA AP mounted to the OBS will be covered with acoustic absorptive panels similar to those used to cover the humidifier (dehumidifier), and sound pressure level data will be recorded.

Because the MDCA CIA cradle fixture has significant surface area, it may be a significant acoustic blocker and or reflector. Therefore, it may be necessary that the MDCA, in its cradle fixture, be rotated 180 degrees about its longitudinal axis and a second set sound pressure level data be recorded.

4.5. Microphone Locations

Six (6) microphone locations arranged in an approximately rectilinear array will be used to measure the sound pressure levels 0.6 meters from the center of each side of the MDCA AP except for the bottom microphone. Because the MDCA AP is mounted on top of the OBS, the bottom microphone will be placed 0.6 meters beneath the bottom of the OBS.

Six (6) microphone locations arranged in an approximately rectilinear array will be used to measure the sound pressure levels 0.6 meters from the each side of the MDCA CIA. A hand held SLM will be used to try to identify the "loudest" (i.e. highest overall A-weighted sound level) locations that are 0.6 meters from each side. If the loudest locations can be satisfactorily identified, microphones will be placed there. Because most of the acoustic noise sources of the MDCA CIA are ether nonstationary (i.e. impulsive, transients) or stationary, but with a relatively short operating period, it is anticipated that the hand held SLM survey may not identify the loudest locations. If the hand held SLM survey cannot satisfactorily identify the loudest location for a particular side, then the microphone will be placed 0.6 meters from the geometric center of that side.

For both the MDCA AP and CIA microphone position #1 will be above, position #2 will be in front, position #3 will be on the right side, position #4 will on the back side, position #5 will be on the left side, and position #6 will be underneath. These microphone positions will be similar to those shown in Figure 12.

These six (6) microphones will be supported with microphone tripod stands and booms and will have windscreens attached during setup to provide physical protection. These windscreens will be removed from the microphones prior to acquiring data. All microphones will face toward the test article.

In addition to these six microphones two additional microphones will be set up. One microphone will be positioned inside the ATL test chamber near the test article for listening purposes. A second microphone, located on the roof of the ATL control room, will be used for noise intrusion monitoring.

The total number of microphones and their location may change during testing depending on the acoustic emissions characteristic of the MDCA CIA or AP. Prior to the start of each day of testing and at the conclusion of each day of testing, all microphones will be calibrated with a pistonphone calibrator.

4.6. Test Conditions

The MDCA AP has one test condition (i.e. test condition #1). The MDCA CIA, both upright and inverted, will be tested while operating in a continuous loop of its operating cycle (i.e. test conditions #2 &#5). The loudest single operational events of the MDCA CIA are when the igniters are moving and the dispenser motor running. If the MDCA CIA is close to or exceeds the Continuous Noise Limits or the Intermittent Noise Limits then the MDCA CIA will be operated with the igniters moving and the dispenser motor operating individually (i.e. test conditions #3, #4, #6, & #7). The test conditions are listed in Table 4. It is expected that the same microphone locations will be used for all test conditions.

5. Data Acquisition.

For each test condition, seven (7) channels of 60 second Leq averaged one-third octave band (50 Hz – 10 kHz) data will be acquired simultaneously, using the National Instruments™ (NI) data acquisition system (Sound Power System with Mutli-Channel Extension software). This sound pressure level

data will be recorded using B&K 2822 multiplexers and B&K 2669 preamplifiers / 4189 microphones.

Ambient sound pressure level spectra will be acquired at the start and completion of testing. These one-third octave band data are automatically output by the NI data acquisition software to multi-sheet Excel workbooks. These workbooks also include a description of the test configuration, transducer calibration data, and other instrumentation data as well as ambient sound pressure level corrections.

The ambient sound pressure level correction limit will be 6 dB, position by position (apply correction below limit). This means that if measured source sound pressure level at an individual microphone position was less than 6 dB above the ambient (background) sound pressure level then the measured corrected source sound pressure level is given by:

$$\text{Corrected Source SPL} = \text{Measured Source SPL (dB)} - 1.3\ \text{dB}.$$

If the measured source sound pressure level at an individual microphone position was greater than 6 dB above the ambient (background) sound pressure level then the measured corrected source sound pressure level is given by:

$$\text{Corrected Source SPL} = 10 * \log 10\,[10\text{^}(\text{Measured Source SPL}/10) - 10\text{^}(\text{Ambient SPL}/10)]$$

The resulting ambient (background) correction of the measured source sound pressure level is shown in Figure 13.

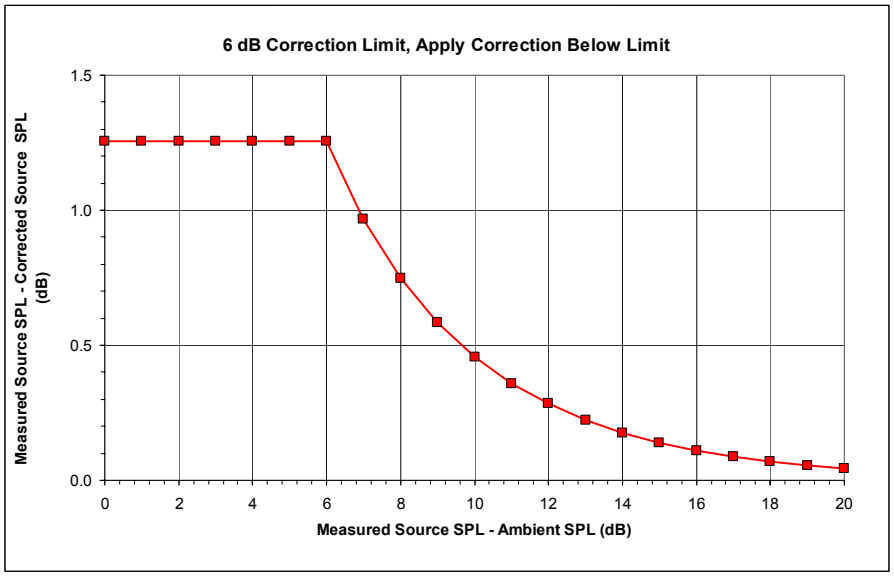

Figure 13. Ambient (background) correction.

For operating conditions that exhibit nonstationary acoustic noise (i.e. impulses, transients, chirps, etc) the maximum overall A-weighted sound level will be acquired with a Larson Davis 2900B using a fast exponential weighting filter, a slow exponential weighting filter, and an impulsive weighting filter. This data will be recorded for the two loudest microphone positions (i.e. having the highest overall A-weighted Leq averaged sound levels). These maximum overall A-weighted sound levels will not (and cannot) be corrected for the ambient (background) sound pressure levels. The overall ambient (background) A-weighted sound levels (Leq averaged) inside the ATL test chamber are on the order of 18 dBA (50 Hz – 10 kHz) with the majority of the ambient sound pressure level spectrum being below 200 Hz, as shown in Figure 14. Therefore the ambient (background) sound pressure levels should not have a significant effect upon maximum overall A-weighted sound levels that are approaching the levels of the Intermittent Acoustic Noise Limits, shown in Figure 15.

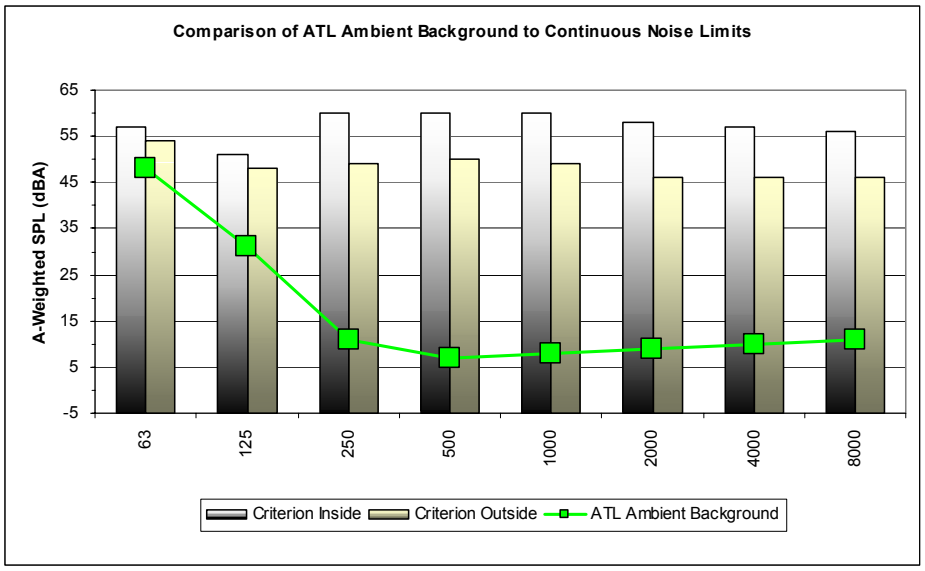

Figure 14. Comparison of the ATL ambient (background) sound pressure level and the Continuous Acoustic Noise Limits.

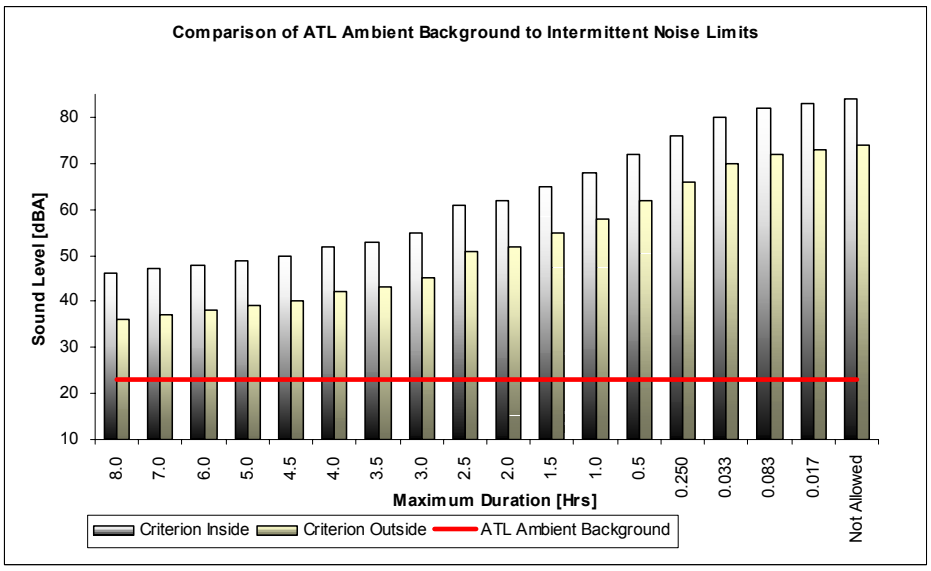

Figure 15. Comparison of the ATL ambient (background) overall A-weighted sound level and the Intermittent Acoustic Noise Limits.

Table 4. MDCA test conditions.

Test Condition #	Test Article	Description (1)
1	AP	Powered up.
2	CIA	Normal operating cycle continuously repeating.
3*	CIA	Igniters moving.
4*	CIA	Dispenser motor operating.
5*	CIA (inverted)	Normal operating cycle continuously repeating.
6*	CIA (inverted)	Igniters moving.
7*	CIA (inverted)	Dispenser motor operating.

Notes:

(1) The OBS cooling fan will be turned off during all data acquisition.

(*) Optional test conditions at the discretion of the test engineer.

All test data will be backed up before breaking for lunch and at the conclusion of each day of testing to guard against accidental loss of data.

6. Data Reporting.

For each test condition, one summary workbook will be synthesized from the (edited) relevant output data workbook from the test runs for that test condition. Each multi-sheet summary workbook will contain all pertinent test data, including ambient sound pressure levels as well as measured (uncorrected) and corrected source sound pressure levels.

Digital photos will be taken to thoroughly document the setup, testing, and tear down. A finalized set of digital photos will be placed in an annotated PowerPoint presentation. Two CD's will be created that each contain a brief test report, all summary workbooks, all digital photos, and the annotated PowerPoint presentation. One CD will be transmitted officially to the NASA project office and the other CD will also be transmitted officially to the Customer